The Oceanic Remote Chemical/Optical Analyzer (ORCA)—An Autonomous Profiler Monitoring Water Quality in South Puget Sound

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Abstract

We have developed an autonomous, moored profiler called the Oceanic Remote Chemical/Optical Analyzer (ORCA) to sense a variety of chemical and optical properties in the upper ocean. It is presently used to monitor water quality parameters in south Puget Sound—a largely undeveloped area subject to extensive future urbanization. ORCA has three main components:

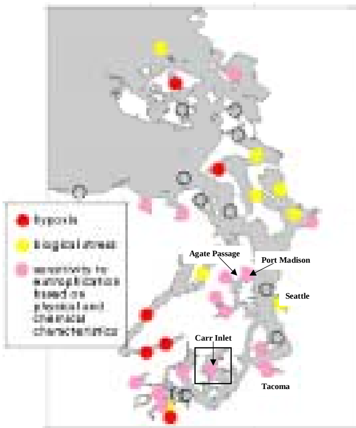
(1) A three-point moored ATLAS toroidal float.
(2) A profiling assembly on the float with computer, winch, cellular system, meteorological sensors (wind, temperature, humidity, irradiance), solar panels and batteries.
(3) An underwater sensor package consisting of a Seabird CTD profiler, YSI dissolved oxygen electrode, Wetlabs transmissometer and Wetlabs Chlorophyll fluorometer.

At regular sampling intervals, ORCA profiles the water column using the winch and pressure information from the CTD. The data is recorded on the computer and transmitted back to the lab automatically via cellular communications. We present data from a seven-month deployment beginning May 26, 2000. The data set reveals the combination of intermittent stratification-mixing and strong seasonal forcing in this estuarine system and drives us to continue our observational and modeling efforts to understand the mechanisms controlling South Puget Sound water quality.

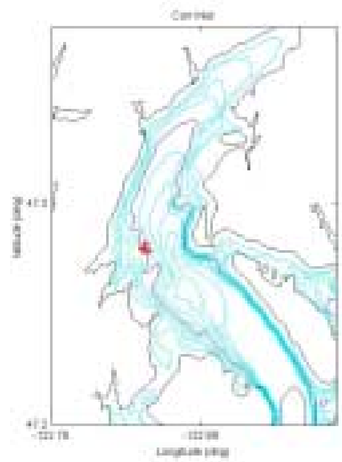
Introduction

South Puget Sound, as the furthest inland region of Puget Sound, consists of many sluggishly circulating inlets and passages. This situation leads to long residence times, low overall flushing and a high shoreline/water area ratio combining to provide a much lower ability to dilute pollution than the main basin of Puget Sound. This sluggish circulation, combined with freshwater input, leads to areas of high physical stratification.

With weakened light limitation and nutrient-rich source waters from the north Pacific, phytoplankton production is high and seasonally variable with episodes of light and nutrient limitation, leading to toxic blooms and depleted bottom water oxygen (Figure 1a). Furthermore, South Puget Sound is expected to undergo intensive urbanization in the next few decades, further increasing inputs of wastewater and other pollutants.



1a)



1b)

Figure 1. (1a) Puget Sound with station locations of Washington State Department of Ecology's Puget Sound Ambient Monitoring Program (PSAMP) marine water monitoring stations. Colors indicate water quality conditions (courtesy of PSAMP). Also shown are locations of ORCA testing and mooring deployments. (1b) Bathymetric contour map of Carr Inlet showing mooring location. Blue lines indicate 10 m contours. Black lines indicate 50 m contours.

This combination of nutrient limitation and urbanization has led us to develop an autonomous observing system for high-resolution time-series measurement of water quality. The purpose of this system is to describe water quality variability on the continuum of time-scales from the tides, through diel, weather, bloom and season cycles, all the way to the inter-annual. This project augments Washington State Puget Sound Ambient Monitoring Program (PSAMP) activities allowing us to better understand the human threat to water quality in Puget Sound through affording a more comprehensive, and ultimately mechanistic understanding of what controls stratification, oxygen, and biomass variability in South Puget Sound. This information will allow us to further our understanding of phytoplankton blooms and predict whether or not they will become more common under increased urbanization. Associated to this, we will develop a much better understanding of oxygen dynamics to gauge whether or not bottom water oxygen levels may decrease to levels hazardous to fish and other organisms.

Methods

ORCA has three main components: a three-point moored float with associated hardware (Figure 2); a profiling assembly; and an underwater sensor package. The float itself is a fiberglass Atlas toroid float with a platform with winch housing, battery housings, superstructure and solar panel attachments and a galvanized steel ring hung below the float as ballast and as the connection point for the three anchor lines. Profiling is accomplished using a computer-controlled winch and hydrowire configuration through the center of the toroid. Currently, ORCA utilizes the following sensors: a Seabird-19 profiling conductivity, temperature and pressure sensor; a YSI dissolved oxygen gas sensor; a Wetlabs transmissometer; and a Wetlabs chlorphyll *a* fluorometer. ORCA underwent an intensive, overnight field test with sensor calibration in Port Madison, Puget Sound (5/11/00-5/12/00). Following this successful deployment, ORCA was moored in Carr Inlet, Puget Sound, on 5/26/00 in approximately 50 m of water, 2 km from shore at latitude 47° 16.771' N, longitude 122° 43.686' W (Figure 1b; Figure 3). The ORCA design is described in further detail elsewhere (Dunne and others submitted).

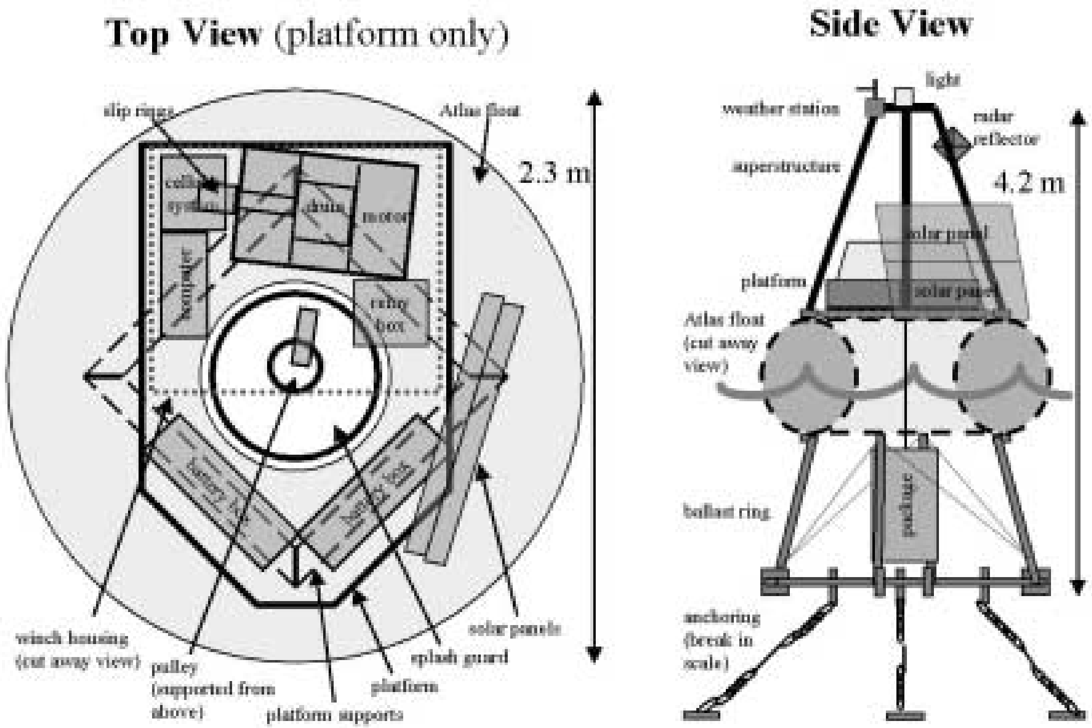


Figure 2. Schematic of ORCA in top view with platform only (superstructure, ballast ring and anchoring removed) and inside view with triple-point mooring assembly.

Figure 3. Picture of ORCA during deployment in Carr Inlet (5/24/00-5/26/00).

Results

During its deployment, ORCA has provided more than 600 profiles of physical and biological conditions in Carr Inlet. We observed a considerable amount of vertical and temporal variability during this period. We summarize these results as monthly averages and standard deviations in Figure 4. In the data set thus far, we have observed seasonal forcing as the primary driver for variability in Carr inlet. This has been observed previously in the PSAMP data set at the coarse temporal resolution allowed by monthly sampling. In addition to the seasonal cycle, we have observed considerable variability on shorter time-scales. A synthesis of this analysis is shown in Table 1. Temperature, salinity and oxygen vary on day to week time-scales, presumably in response to weather events during the late spring, summer and early fall. During these events, stratification is broken down but quickly re-established, allowing for replenishment of depleted bottom-water oxygen levels and a re-supply of nutrients to well-lit surface waters to further phytoplankton growth. As a consequence of this physical variability, variability in chlorophyll fluorescence is well distributed across time-scales, with almost half of the annual variability occurring over time-scales less than a month. Biology is thus strongly impacted by the short-term physical variability with the phytoplankton community getting essentially re-set during each physical event. We also observe asynoptic variability (variability on time-scales less than our specified sampling resolution of slack time - ~ every six hours) in all parameters. This suggests the presents of eddies and/or fronts near our site. Results of this deployment are described in further detail elsewhere (Dunne and others submitted).

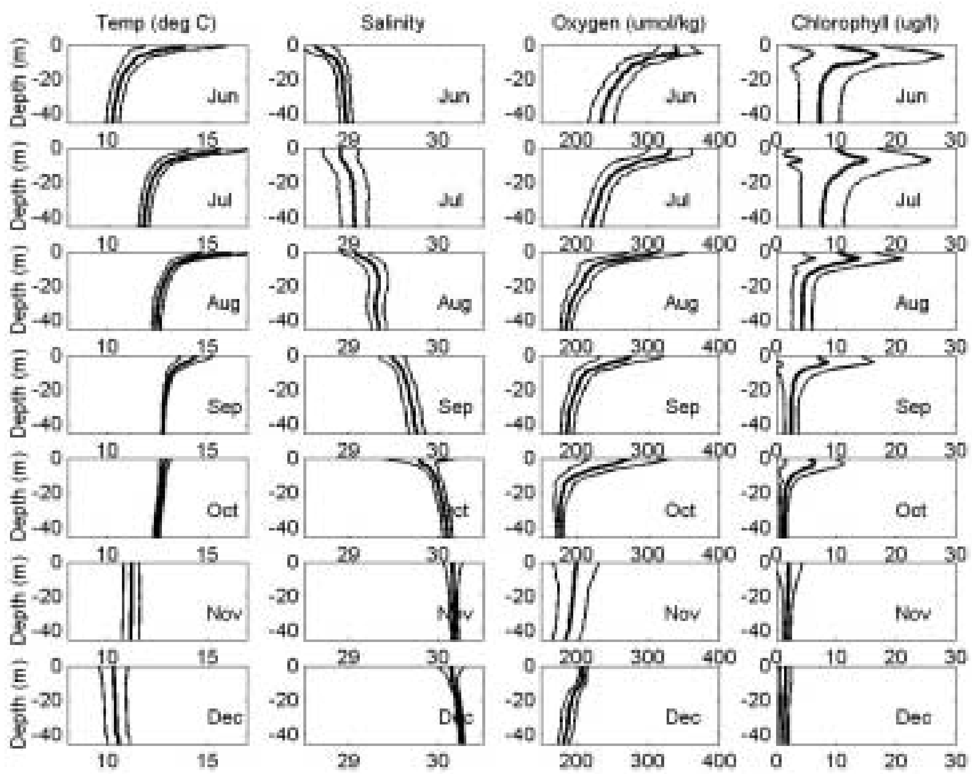


Figure 4. Monthly averages and standard deviations in June through December, 2000 temperature (ºC), salinity, density (σ_t), oxygen (µM), and chlorophyll fluorometry (µg/l) - versus depth (m) from Carr Inlet.

Table 1: Component of variance (%) in tidal, day, week, and month time-scales for temperature, salinity, oxygen and chlorophyll fluorometry from the ORCA data set in the 0-10m-depth interval.

Timescale	T (%)	S (%)	O_2 (%)	Chl (%)
<tide	5	1	6	7
tide-day	3	1	1	8
day-week	12	5	12	18
week-month	9	1	3	15
>month	71	92	79	52

Summary

We have developed ORCA as an autonomous profiler to monitor water quality in Puget Sound. ORCA can perform high-resolution water column profiling over long time scales. This intensive, time-series sampling can provide vital context for process studies and regional surveys and would be particularly well complemented by additional time-series work in the Tacoma Narrows and main Basin. The next steps in this project will be to add sensors, continue the measurement program and model temporal variability in stratification and oxygen response in Carr Inlet. We plan to add optical sensors for photosynthesically active radiation (PAR) and spectral optics (AC-9), chemical sensors for dissolved gases (N_2, O_2) and nutrients, a meteorological system, and an acoustic Doppler current profiler. We plan higher resolution sampling for spring bloom in 2001 and have begun to develop a model stratification and oxygen response in Carr Inlet that we will validate against the ORCA data with the goal of gaining a predictive capacity for water quality.

Acknowledgements

The authors are particularly thankful for the expert advice and assistance received from Rex Johnson, Steve Elliot and Ray McQuin, and Jan Newton at UW Oceanography. This research was supported by the Environmental Protection Agency STAR Program Grant R826942. John Dunne was supported by the UW Puget Sound Model (PRISM) initiative.

Reference

Dunne, J. P., Devol, A. H. and Emerson, S., submitted, The Oceanic Remote Chemical/optical Analyzer (ORCA)—an autonomous moored profiler. Journal of Atmospheric and Oceanic Technology